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26 Settembre 1979

M. Greco, G. Pancheri-Srivastava and Y. Srivastava :

RADIATIVE CORRECTIONS TO $e^+e^- \rightarrow \mu^+\mu^-$ NEAR THE Z_o-RESONANCE WITH TRANSVERSELY POLARIZED BEAMS.

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M. Greco, G. Pancheri-Srivastava[x] and Y. Srivastava[x][o]: RADIATIVE CORRECTIONS TO $e^+e^- \to \mu^+\mu^-$ NEAR THE Z_o-RESONANCE WITH TRANSVERSELY POLARIZED BEAMS.

In this note we present radiatively corrected expressions for the process $e^+e^- \to \mu^+\mu^-$ in the vicinity of the Z_o mass, for transversely polarized beams. Our results generalize those of a previous work[1] discussing the unpolarized case. The range of validity of our formulae, as well as the notations used, are the same as in ref. (1). As before, we work in the framework of the Weinberg-Salam model[2].

Formulae.

The differential cross section can be written as follows:

$$\left(\frac{d\sigma}{d\Omega}\right)^{corr} = C^{res}_{infra}\left(\frac{d\sigma_{res}}{d\Omega}\right)(1+C^{res}_F) + C^{int,V}_{infra}\left(\frac{d\sigma_{int,V}}{d\Omega}\right)\cdot$$

$$\cdot\,(1 + C^{int,V}_F) + C^{int,A}_{infra}\left(\frac{d\sigma_{int,A}}{d\Omega}\right)(1 + C^{int,A}_F) +$$

$$+ C^{int,VA}_{infra}\left(\frac{d\sigma_{int,VA}}{d\Omega}\right)(1 + C^{int,VA}_F) + \qquad (1)$$

$$+ C^{QED}_{infra}\left(\frac{d\sigma_{QED}}{d\Omega}\right)(1 + C^{QED}_F)\,,$$

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where the Born cross sections are given by[1, 3]

$$\left(\frac{d\sigma_{QED}}{d\Omega}\right) = \frac{\alpha^2}{4s}\left(1 + z^2 - \left|\xi_+ \xi_-\right| \sin^2\theta \cos 2\phi\right), \tag{2a}$$

$$\left(\frac{d\sigma_{int,V}}{d\Omega}\right) = \frac{\alpha^2}{4s}\left(1 + z^2 - \left|\xi_+ \xi_-\right| \sin^2\theta \cos 2\phi\right)(2\,\mathrm{Re}\,\chi)\, r_V, \tag{2b}$$

$$\left(\frac{d\sigma_{int,A}}{d\Omega}\right) = \frac{\alpha^2}{4s}(2z)(2\,\mathrm{Re}\,\chi)\, r_A, \tag{2c}$$

$$\left(\frac{d\sigma_{int,VA}}{d\Omega}\right) = \frac{\alpha^2}{4s}\left|\xi_+ \xi_-\right| \sin^2\theta \sin 2\phi (2\,\mathrm{Im}\,\chi)\, r_{AV}, \tag{2d}$$

$$\left(\frac{d\sigma_{res}}{d\Omega}\right) = \frac{\alpha^2}{4s}\left\{1 + z^2 + 8z\, r_A r_V - \left|\xi_+ \xi_-\right| \sin^2\theta \cos 2\phi (r_V^2 - r_A^2)\right\}\left|\chi\right|^2, \tag{2e}$$

with $z = \cos\theta$, $\xi_{(\pm)}$ the polarization of the $e^{(\pm)}$ beam along the direction of the magnetic field and (θ, ϕ) refer to the μ^- with respect to the e^-. As in ref. (1) we have defined

$$r_V = \frac{g_V^2}{g_V^2 + g_A^2} = \frac{(1 - 4\sin^2\theta_W)^2}{1 + (1 - 4\sin^2\theta_W)^2}, \tag{3a}$$

$$r_A = \frac{g_A^2}{g_V^2 + g_A^2} = \frac{1}{1 + (1 - 4\sin^2\theta_W)^2}, \tag{3b}$$

$$r_{AV} = \frac{g_A g_V}{g_V^2 + g_A^2} = \frac{4\sin^2\theta_W - 1}{1 + (1 - 4\sin^2\theta_W)^2}, \tag{3c}$$

and

$$\chi(s) = \left(\frac{3\Gamma_e}{\alpha M}\right)\left(\frac{s}{s - M^2 + iM\Gamma}\right). \tag{4}$$

Infrared Factors.

The factors C^{res}_{infra}, $C^{int,V}_{infra} = C^{int,A}_{infra} = C^{int,VA}_{infra}$ and C^{QED}_{infra} in eq. (1), which take into account the contributions from soft photons to all orders, are the same as in ref. (1).

Finite Contributions to order α.

By extending the calculations of ref. (1) to the polarized case we find[4]

$$C_F^{QED} = \frac{13}{12}(\beta_e+\beta_\mu) + \frac{2\alpha}{\pi}\left(\frac{\pi^2}{3} - \frac{17}{18}\right) + \delta_{VP} + X_V^{pol} \,, \tag{5a}$$

$$C_F^{int,V} = \frac{11}{12}(\beta_e+\beta_\mu) + \frac{2\alpha}{\pi}\left(\frac{\pi^2}{3} - \frac{13}{18}\right) + \frac{1}{2}\delta_{VP} + \frac{1}{2}X_V^{pol} \,, \tag{5b}$$

$$C_F^{int,A} = \frac{11}{12}(\beta_e+\beta_\mu) + \frac{2\alpha}{\pi}\left(\frac{\pi^2}{3} - \frac{13}{18}\right) + \frac{1}{2}\delta_{VP} + \frac{1}{2}X_A^{pol} \,, \tag{5c}$$

$$C_F^{int,VA} = \frac{11}{12}(\beta_e+\beta_\mu) + \frac{2\alpha}{\pi}\left(\frac{\pi^2}{3} - \frac{13}{18}\right) + \frac{1}{2}\delta_{VP} + \frac{1}{2}X_{AV}^{pol} \,, \tag{5d}$$

$$\begin{aligned} C_F^{res} = {} & \frac{3}{4}(\beta_e+\beta_\mu) + \frac{2\alpha}{\pi}\left(\frac{\pi^2}{3} - \frac{1}{2}\right) + \\ & + \frac{1}{1 + \frac{8z}{1+z^2} r_V r_A - \frac{|\xi_+ \xi_-| \sin^2\theta \cos 2\phi}{1+z^2}(r_V^2 - r_A^2)} \cdot \\ & \cdot \left\{ r_V \left[Y_V^{pol} + \frac{2\bar{R}\alpha}{9}\left(\frac{\alpha \Gamma M^2}{\Gamma_e s}\right)\left(1 - \frac{|\xi_+ \xi_-| \sin^2\theta \cos 2\phi}{1+z^2}\right)\right] + \right. \\ & \left. + r_A \left[Y_A^{pol} + \frac{2\alpha\bar{R}}{9}\left(\frac{\alpha\Gamma M^2}{\Gamma_e s}\right)\frac{2z}{1+z^2}\right]\right\} \end{aligned} \tag{5e}$$

where

$$X_V^{pol} = -\frac{\alpha}{\pi}\left\{ z\left(\frac{\ln^2 a}{b^4} + \frac{\ln^2 b}{a^4}\right) - \left(\frac{\ln a}{b^2} - \frac{\ln b}{a^2}\right) + 4\left[\ln^2 b - \ln^2 a + \right.\right.$$

$$\left. + \frac{1}{2}\,Li_2(a^2) - \frac{1}{2}\,Li_2(b^2)\right] + \frac{2z}{1+z^2 - \left|\xi_+\xi_-\right| \sin^2\theta\cos 2\phi} \cdot \tag{6a}$$

$$\left.\cdot\left[z\left(\frac{\ln^2 a}{b^4} - \frac{\ln^2 b}{a^4}\right) - \left(\frac{\ln a}{b^2} + \frac{\ln b}{a^2}\right)\right]\right\},$$

$$X_A^{pol} = X_A - \frac{\alpha}{2\pi}\,\frac{\left|\xi_+\xi_-\right|\sin^2\theta\cos 2\phi}{z} \cdot \tag{6b}$$

$$\cdot\left[z\left(\frac{\ln^2 a}{b^4} - \frac{\ln^2 b}{a^4}\right) - \left(\frac{\ln a}{b^2} + \frac{\ln b}{a^2}\right)\right],$$

$$X_{AV}^{pol} = -\frac{2\alpha}{\pi}\left\{ z\,\frac{\ln^2 b}{a^4} + \frac{\ln b}{a^2} + 2(\ln^2 b - \ln^2 a) + Li_2(a^2) - Li_2(b^2) - \right. \tag{6c}$$

$$\left. - \pi\,\frac{Re\,\chi}{Im\,\chi}\left[z\,\frac{\ln b}{a^4} - 2\ln\left(\frac{a}{b}\right) + \frac{1}{1-z} + \frac{1}{3}\,\bar{R}\right]\right\},$$

$$Y_V^{pol} = Y_V + \frac{2\alpha}{3}\left(\frac{\alpha\Gamma M^2}{\Gamma_e\, s}\right)\frac{\left|\xi_+\xi_-\right|\sin^2\theta\cos 2\phi}{1+z^2} \cdot \tag{6d}$$

$$\cdot\left\{ 2\ln\frac{a}{b} - \frac{1}{2}\,z\left(\frac{\ln a}{b^4} + \frac{\ln b}{a^4}\right) - \frac{z}{1-z^2}\right\},$$

$$Y_A^{pol} = Y_A - \frac{2\alpha}{3}\left(\frac{\alpha\Gamma M^2}{\Gamma_e\, s}\right)\frac{\left|\xi_+\xi_-\right|\sin^2\theta\cos 2\phi}{1+z^2} \cdot \tag{6e}$$

$$\cdot\left\{ \frac{1}{1-z^2} - \frac{1}{2}\,z\left(\frac{\ln a}{b^4} - \frac{\ln b}{a^4}\right)\right\},$$

and the quantities X_A, Y_A, Y_V and $\bar{R}$ are defined in ref. (1).

A more complete discussion and details of the derivation shall be presented elsewhere.

References.

(1) - M. Greco, G. Pancheri-Srivastava and Y. Srivastava, ECFA-LEP SS/7/9, and Frascati Report LNF-79/20 (1979).
(2) - S. Weinberg, Phys. Rev. Letters 19, 1264 (1967); A. Salam, Proc. 8th Nobel Symposium, Stockholm 1968, ed. by N. Svartholm (Almquist and Wiksells, 1968), pag. 367.
(3) - See for example M. Gourdin, ECFA-LEP SSG/7/3 for the most general case of axial and vector couplings, as well as in presence of longitudinal polarization of the $e^{\pm}$ beams.
(4) - For the case of a pure vector coupling, see also M. Greco and A. Grillo, Lett. Nuovo Cimento 15, 174 (1976).